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In the beginning: the multiple discovery of the first hormone herbicides

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The discovery of the first systemic or hormone herbicides, 2,4-D, 2,4,5-T, and MCPA, initiated an agricultural revolution and modern weed science. The finding of these herbicides was a striking case of multiple independent discovery by four groups of workers in two countries, the United Kingdom and the United States: William G. Templeman and associates at Imperial Chemical Industries; Philip S. Nutman and associates at the Rothamsted Agricultural Experiment Station; Franklin D. Jones at the American Chemical Paint Company; and Ezra Kraus, John Mitchell, and associates at the University of Chicago and the U.S. Department of Agriculture. Because of wartime and commercial secrecy, the usual procedures of scientific publication and patent disclosure were not followed; instead, the first scientific report on these herbicides occurred in a publication by workers who were not original discoverers. Considerable confusion consequently resulted concerning the discovery and the discoverers. This confusion has not been completely dispelled in subsequent years. The present report summarizes the complete story, clarifies the chronology of the discoverers and their publications, and makes the case that all four groups of workers deserve credit for this revolutionary advance. The scientific background of the discovery and events in its immediate aftermath, especially the ticklish patent situation, are also briefly chronicled.

Nomenclature: 2,4-D; MCPA; 2,4,5-T.

Key words: History, World War II secrecy, scientific publication, patent disclosure.

When the first systemic or hormone herbicides burst meteorically upon the technological scene in the 1940s, their use initiated an agricultural revolution and laid the corner stone of present-day weed science. These chemical agents, the chlorophenoxyacetic acids 2,4-D, 2,4,5-T, and MCPA, could kill many weeds selectively in small and relatively inexpensive quantities; they "transformed agriculture and are considered to be amongst the greatest scientific discoveries" of the twentieth century (Fryer 1980, p. 1). In the first issue of this journal, Willard (1951, p. 9) called 2,4-D "the catalyst which generated the recent and continuing explosive reaction concerning plant control by chemical means." Half a century later it remains one of the most widely used herbicides in the world (Szmedra 1997). These herbicides and others developed later made the control of weeds no longer a matter of hazardous corrosive chemicals, hit-or-miss results, or hard manual labor. The poet's Man With The Hoe, "bowed by the weight of centuries . . . and on his back the burden of the world" (Markham 1899) became the man erect riding the mechanized sprayer or duster.

The finding of these first hormone herbicides was a striking case of multiple independent discovery. Four workers or groups of workers in two countries, the United Kingdom and the United States, made the discovery, each laboring without knowledge of the others' efforts. Because of conditions prevailing at the time, the discoverers did not follow usual procedures of scientific publication and patent disclosure, but announced their findings in a sequence that did not reflect the actual order of discovery. A further complication occurred when workers who were not original discoverers produced the first report on these herbicides to appear in a scientific publication.

The result was confusion concerning who the discoverers were and when their discoveries were made. Minarik (1946, p. 113) wrote that "the originators of the idea that plant growth regulators might be herbicides is a controversial point." Four decades later Fletcher and Kirkwood (1982, p. 22) still stated that it was "difficult to establish precedence for the precise discovery of 2,4-D as a herbicide." Some confusion continues to the present. For example, two recent accounts from the United States (Bovey and Young 1980; Canine 1995) do not mention the British work at all, and two from the United Kingdom (Lockhart et al. 1990; Blaxter and Robertson 1995) discuss the British discoveries but merely mention only that "parallel work" or "independent work" occurred in the United States.

Two historical studies of the discovery of the herbicides have dispelled some, but not all, of the confusion. Peterson (1967) provided a detailed and well-documented description of one program in the United States, but alluded to the British work in only one brief note. Kirby (1980) supplied a more balanced account of both the British and American work. Her discussion, however, contains some minor inaccuracies concerning the latter and, more important for historians, is only lightly referenced. These two studies taken together account for three of the four groups of discoverers. Both authors mention the fourth, Franklin D. Jones, receiver of the first United States patent on chlorophenoxyacetic acids as herbicides, but they do not regard him as an original discoverer. They both record that he provided 2,4-D to the other American group, and both cite his patent. However, Kirby (1980, p. 6) clearly concludes that the discovery was made by "three quite independent groups, two

in the United Kingdom and one in the United States of America," not including Jones.

The purposes of this communication are to summarize the complete story, to clarify the dates when all four groups made their independent discoveries, to provide additional references to the primary literature not given by Peterson or Kirby, and to point out that the claim of Jones to the discovery is quite as good as those of the other three groups.

Scientific Background of the Discovery

A scientific discovery, even a revolutionary one, does not come suddenly out of the blue or burst from the head of the discoverer like Athena from Zeus. While talent and insight play their parts, a body of previous knowledge always leads a discoverer to ask the right experimental questions. Thus, a scientific background underlay the discovery of the first hormone herbicides. Although false starts, dead ends, and outright errors occurred along the way, hindsight can discern a direct line of development. Interestingly, the major advances in this line involved five additional cases of multiple independent discovery.

In the last quarter of the nineteenth century botanists learned that a growth response of a plant part to an external stimulus such as light or gravity may occur in a region of that part different from the one that receives the stimulus. This fact, which suggests that some agent forms a connection between the receptive and responding regions, was established independently by three workers (Ciesielski 1872 for roots; Darwin 1880 for coleoptiles; Vöchting 1888 for leaves). Then around 1910, two researchers separately demonstrated that such agents promoting plant growth were chemical substances, termed "hormones" (Boysen Jensen 1910, 1911, 1913; Fitting 1909, 1910). Subsequently two groups of workers independently identified the first chemical known to have growth-promoting properties, indoleacetic acid (Kögl et al. 1934a; Kögl and Kostermans 1934; Thimann and Koepfli 1935). These groups then both showed that the same substance could also inhibit or reduce growth if applied at higher concentrations (Kögl et al. 1934b; Skoog and Thimann 1934). Several workers soon found simultaneously that certain synthetic chemicals, similar to indoleacetic acid but not occurring naturally in plants, could cause similar growth effects (Haagen Smit and Went 1935; Hitchcock 1935; Thimann 1935; Zimmerman and Wilcoxon 1935). The term "auxin" was applied to any substance having these properties. Several years later, three independent groups demonstrated that naphthoxyacetic acid is an auxin (Bausor 1939; Irvine 1938; Zimmerman et al. 1939). This finding was an important step because it led workers to study other substances having a different molecular ring structure connected to acetic acid by an oxygen link, such as, eventually, the phenoxyacetic acids. By 1940, a large number of chemical agents were known to produce a bewildering array of effects on plant growth, some of which were of practical agricultural and horticultural value (Wittwer 1971).

This was an era of shotgun experimentation on the effects of chemicals on plant growth. In this atmosphere, a few researchers tried applying auxins to intact whole plants in an effort to promote their growth and thus possibly increase crop yields (Tincker 1941). The results were confusing. Frequently there was no effect, but sometimes promotion and sometimes inhibition occurred. High concentrations of certain agents, especially, inhibited growth, and most significantly, some results suggested that different plant species vary in their tolerance of such high levels. Attention to this fact led the four groups of workers to consider the possible use of auxins as weedkillers and eventually to make their revolutionary advance.

Discovery in the United Kingdom

Discovery at Imperial Chemical Industries

First to accomplish the discovery was William Gladstone Templeman, working in the United Kingdom at the Jealott's Hill Research Station of Imperial Chemical Industries (ICI). Born in 1911, Templeman had received the M.Sc. and Ph.D. degrees in botany and plant physiology from King's College and then joined ICI. He had a distinguished career, later serving as deputy director of his research station, as vice president of the Linnean Society, and as president of the Fertilizer Society (Anonymous 1953a). But when he came to ICI in 1933 he was a young researcher assigned the general task of finding chemicals to increase plant growth. Other persons associated with him in this work were Wilfred A. Sexton of the Dyestuffs Division of the company, who selected compounds to be tested, and Roland E. Slade, who was overall research controller. Templeman, however, conducted the actual experiments with plants.

Studies carried out by Templeman in 1936 and 1937 showed toxic effects of indoleacetic acid and naphthaleneacetic acid applied to whole plants—effects that seemed to vary with different plant species (Templeman 1939). He confirmed these results for additional kinds of plants in August 1940 but published the findings only later (Slade et al. 1945; Templeman and Sexton 1946). In that same year he showed that these growth substances applied appropriately would kill certain broad-leaved weeds in cereals without harming the grain crops (Templeman and Marmory 1940). The compounds were, however, too expensive and too quickly degraded by microorganisms in the soil to be of practical agricultural use. He therefore enlisted the aid of ICI chemists, who in 1940 provided 32 related substances among which were the phenoxyacetic acids 2,4-D and MCPA. The first mention of acids of this type in the chemical literature appeared in June 1941 by an American industrial chemist who described their syntheses without noting any biological effects (Pokorny 1941). The ICI chemists had obviously accomplished such syntheses earlier. Templeman found 2,4-D and MCPA to be extremely effective as differential or selective herbicides for weeds in cereals. The use of these two substances for that purpose was the subject of a patent application filed in April 1941. World War II was then under way, however, and the British government restricted scientific publication and patent disclosure. Consequently Templeman's results and the patent were not revealed publicly until 1945 and 1946 (Slade et al. 1945; Sexton et al. 1945; Templeman 1945, 1946; Templeman and Sexton 1946). Later accounts of Templeman's work may be found in Templeman (1955), Russell (1966), Burnet (1967), Allen at al. (1978), Kirby (1980), and Kennedy (1993).

In the course of Templeman's work, another example of

multiple discovery became intertwined with that of the hormone weedkillers. In finding the selective herbicidal action of the chlorophenoxyacetic acids, Templeman necessarily also learned that these compounds are active as auxins when applied appropriately, since their use as weedkillers depends on such activity. Although he clearly was aware of this before the date of his patent application in 1941, the fact was not then publicly known. The first open publication that 2,4-D is an auxin was that of Zimmerman and Hitchcock (1942) of the Boyce Thompson Institute in the United States. Their paper was preprinted on April 18 and issued on July 29; between these dates an announcement of their results appeared on May 8 (Anonymous 1942). Unknown to them was the fact that John Lontz, a chemist with the E. I. DuPont de Nemours Company, had also been working with this class of compounds and had on February 20, 1942, already applied for a United States patent on their use as plant growth regulators (Lontz 1943). In that same month, the biological activity of 2,4-D was also found by Franklin D. Jones (Jones 1953), whose discovery of the herbicidal action of the chemical is detailed later. Initially unaware of each other's work, these American researchers also did not know that they had all been preceded by Templeman. Since all four sets of workers worked independently, this was also a case of quadruple discovery.

Discovery at Rothamsted

When in accordance with wartime regulations the workers at ICI reported their discovery of the selective herbicidal action of 2,4-D and MCPA to the British Agricultural Research Council in November 1942, they received a shock. The same discovery had been made independently by researchers at the Rothamsted Agricultural Experiment Station. There, beginning in November 1941, Philip S. Nutman, H. Gerard Thornton, and John H. Quastel had been studying the involvement of auxins in the process of nodule formation in legume roots by symbiotic bacteria. That process, important in the fixation of atmospheric nitrogen and thus in soil fertility, was seemingly far-removed from the problem of weed control. In the course of their studies, these workers found that in sterilized soil, indoleacetic and naphthaleneacetic acids at appropriate concentrations could be extremely toxic to clover (*Trifolium* spp.) and other broadleaved plants but not to wheat (*Triticum aestivum* L.). They saw from this result that it might be possible to use these compounds in selectively controlling plant growth. They also found, however, that the activity of these compounds was quickly lost in unsterilized soil, presumably because of destruction by soil microorganisms. Such substances would therefore be of no practical use under natural conditions. Then in 1942, Quastel visited the Boyce Thompson Institute in the United States, where he learned of the auxin activity of 2,4-D (Kirby 1980). Upon returning to Rothamsted, he suggested trying this chemical in their experiments, reasoning that chlorinated compounds might be resistant to microbiological destruction. In October 1942 the group found that 2,4-D was indeed extremely effective in natural soils. Again because of wartime restrictions, these workers could not publish their results until 1945 and 1946 (Nutman et al. 1945; Rothamsted Agricultural Experiment Station 1946). They did, however, report them in November 1942 to the Agricultural Research Council with the suggestion that 2,4-D might have importance as a wartime weapon of crop destruction (Russell 1966; Kirby 1980).

Extensive Field Trials

When the Agricultural Research Council learned that two groups of workers had independently discovered a class of chemicals that might have enormous importance in agriculture and also the potential for wartime crop destruction, it acted quickly (Kirby 1980). It was motivated both by the need to save labor in weed control and by concern that enemy scientists might have made the same discovery. All work on the chemical agents was therefore consolidated into one large program led by the workers at ICI, and practical field trials under actual agricultural conditions were immediately scheduled. Small-scale investigations were carried out in Norfolk in 1943 and larger programs in 1944. In 1945, the year the war ended, the most extensive field trials carried out in Britain to that time were conducted. ICI alone performed tests at 111 centers covering over 400 ha in 23 counties. Other groups brought the totals to over 1,000 centers and 5,200 ha. Details of this field effort were not published until 1945 and 1946. Blackman (1945a, 1945b, 1946) described his part in the field program; other accounts were those of Duncan (1946), Hudson (1946), Templeman (1946), and Burnet (1967). The field studies were also referred to in a press release from ICI in March 1945 (Anonymous 1945a, 1945b, 1945c), as well as in a press conference held by the company in October of that year (Anonymous 1945d, 1945e).

Discovery in the United States

Discovery at American Chemical Paint Company

While these events were unfolding in the United Kingdom, two independent discoveries of the hormone herbicides occurred in the United States. One of these was by Franklin D. Jones. Born in 1898, Jones worked as a chemist with a number of industrial companies after graduating from Bucknell University in 1919 (Cattell 1960). In 1938 the American Chemical Paint Company, later known as Amchem Products Company and, after several mergers, now part of Aventis, became interested in the manufacture of growth-regulating chemicals for use in agriculture and horticulture (Haynes 1949). Jones became manager of the agricultural department of the company in that year and served as such until 1947. In his early years with the company, he obtained a number of patents covering the use of various chemicals in promoting plant growth. Information concerning Jones' work on herbicides is scattered among a number of sources (Anonymous 1945f; Carleton 1945; Cates 1945; Jones 1945a, 1945b, 1946; Snyder 1945). In February 1942 he set out to find an agent to kill poison-ivy [*Toxicodendron radicans* (L.) Ktze], motivated in this effort not only by commercial considerations but also by the fact that his children were unusually susceptible to poisoning by this plant. Just at this time, Zimmerman and Hitchcock reported on the growth-promoting properties of 2,4-D, so Jones incorporated such compounds in his studies. He found that both 2,4-D and 2,4,5-T were powerfully effective. During the following 2 yr he performed more than 100 experiments on their selective action against numerous

TABLE 1. Dates of independent discovery and disclosure of results on chlorophenoxyacetic acid herbicides by four groups of researchers.

Researchers	Organization	Work begun on chlorophenoxyacetic acid herbicides	First disclosure of original work of discovery
Templeman and associates	Imperial Chemical Industries, U.K.	1940	British patent application April 7, 1941; issued Dec 13, 1945 Report in *Nature*, April 28, 1945 Report in *Proceedings of the Royal Society*, submitted Nov 8, 1944, published Aug 7, 1946
Jones	American Chemical Paint Company, United States	Feb 1942	Canadian patent application June 2, 1944, U.S. patent issued Dec 11, 1945 Report in *American Nurseryman*, presented Feb 8, 1945, published March 1, 1945
Nutman, Thornton, Quastel	Rothamsted Agricultural Experiment Station, U.K.	Oct 1942	Report in *Nature*, April 28, 1945 Report in *Rothamsted Report for 1939–1945*, published 1946
Kraus, Mitchell and associates	University of Chicago; Beltsville Experiment Station, United States	Jan 1943 March 1943	Report in *Botanical Gazette*, March 1947 Report in *Botanical Gazette*, Dec 1944

plants. On the basis of the results, in June 1944 he applied for a Canadian patent on the use of these compounds as weedkillers; he followed this with an application in the United States in May 1945. The patent was actually issued in December 1945 (Jones 1945c).

Discovery at Chicago and Beltsville

The fourth discovery, second in the United States, was treated exhaustively by Peterson (1967) but may be summarized briefly here. In 1941 Ezra J. Kraus was a plant physiologist and chairman of the Department of Botany at the University of Chicago. He was interested in various research problems, among which was the action of growth-regulating substances on plants. In August of that year he wrote privately to two of his former graduate students, plant physiologists John W. Mitchell and Charles L. Hamner. Mitchell had earned the Ph.D. degree at Chicago in 1932, and Hamner in 1940. The two were then working in the United States Department of Agriculture in Beltsville, MD. In his letter, Kraus suggested that auxins might be useful as herbicides if applied in doses high enough to be toxic. Hamner and Tukey (1944a), Marth and Mitchell (1944), and Norman (1946) subsequently credited Kraus with this suggestion. It led in 1941 and 1942 to cooperative studies by Kraus at Chicago and Mitchell and his associates at Beltsville, principally Hamner and Paul C. Marth. After Zimmerman and Hitchcock reported that chlorophenoxyacetic acids were auxins, Kraus and Mitchell began work in 1943 with 2,4-D and 2,4,5-T in January at Chicago and in March at Beltsville. Results soon indicated that at appropriate concentrations these compounds killed broad-leaved plants without harming cereals.

Kraus made this fact known to persons concerned with military efforts of World War II, pointing out that such chemicals might be used to destroy crops. Subsequently, the research of this group became part of an extensive program on biological warfare in which herbicide research was done by the Special Projects Division of the Chemical Warfare Service of the United States Army. New laboratories for this division were built at Camp Detrick, MD, and it became the largest element of the Chemical Warfare Service, with a peak complement of over 4,000 persons (Brophy et al. 1959). In 1944 and 1945 it screened more than 1,000 compounds for herbicidal activity. Ironically, this huge effort uncovered no new herbicides; the most active and suitable ones were the 2,4-D and 2,4,5-T which Kraus and Mitchell had found initially (Anonymous 1946a; Special Products Division 1946; Merck 1946a, 1946b). After becoming part of the army program, Kraus and Mitchell were subject to censorship according to strict rules of wartime military secrecy. Although such restrictions were removed in September 1945 (Kraus 1945), they did not publish the results of their discovery until March 1947 (Kraus and Mitchell 1947). In the meantime, work actually done later could be published in December 1944 because it emanated from the Department of Agriculture, not from the military program (Marth and Mitchell 1944).

Chronological Summary

A Quadruple Discovery

Table 1 summarizes the rather complicated chronology of this fourfold discovery of the hormone herbicides. In it, the discoverers are listed in the order in which they began work on the chlorophenoxyacetic acids: Templeman in 1940, Jones and the Rothamsted group in 1942, and Kraus and Mitchell in 1943. This case is clearly a striking example of multiple independent discovery, a kind of discovery that "occurs when two or more scientists or inventors give expression to the same theory, discover similar phenomena, or invent or design similar instruments and apparatuses" (Lamb and Easton 1984, p. ix) and "has been widely noted in the sciences" (Cozzens 1989, p. 1). Indeed, since the seminal work of Merton (1961), sociologists and historians of science have found multiples to be of common occurrence and have treated such questions as what constitutes them, how to recognize and define them, and what causes them to occur. The sociological literature on multiple discovery has been summarized by Zuckerman (1988).

The four groups of researchers who gave agriculture MCPA, 2,4-D, and 2,4,5-T certainly worked independently. As Mendelssohn (1977, p. 9) put it, "they did not crib from

each other or look over each other's shoulder." They found the same substances and the same effects, and they did so at about the same time. As Mendelssohn (1977, p. 9) further observed, "these discoveries were never independent when the state of scientific knowledge as a whole is considered." One might thus argue that, given the scientific information about plant growth regulators available at the time, someone else could have made the discovery. But these workers did so. All of them deserve credit for it, and all should be lauded for the keenly receptive minds that led them to it.

Publication of the Discovery

As previously indicated and summarized in Table 1, publication of their results by the original discoverers occurred in 1945, 1946, and 1947 in a time sequence different from that in which they did their work. Announcement of the British results was delayed by wartime governmental restrictions. In the United States similar regulations prevented immediate publication by Kraus and Mitchell, and Jones remained silent for commercial reasons until his patent was well in progress.

The publication situation was even further beclouded. To the surprise and perhaps consternation of the British workers, announcements that the chlorophenoxyacetic acids are selective herbicides occurred first in the United States. Furthermore, these were based on results from experiments performed quickly in 1944 which were not part of the original discoveries and were not subject to secrecy. Although a paper from Beltsville in June 1944 suggested that 2,4-D might be useful as an herbicide (Mitchell and Hamner 1944), the first scientific publication to provide actual data was by workers at the New York Agricultural Experiment Station. Hamner was familiar with the work at Beltsville from having worked there with Mitchell. When he moved to the New York station in July 1944 (Cattell 1955), he and H. B. Tukey performed an agricultural experiment with 2,4-D and 2,4,5-T. They initiated this experiment on the 14th of that month and published the results in August (Hamner and Tukey 1944a). With this publication, the cat was out of the bag. In August and September Mitchell and associates treated golf course turf with 2,4-D and published the results in October in a nontechnical journal (Mitchell et al. 1944). In November, an open discussion of 2,4-D occurred at a weed control conference (Kephart and Griffin 1944). Then in December, some strictly agricultural results appeared from Beltsville (Marth and Mitchell 1944) and more complete data from New York (Hamner and Tukey 1944b). Over subsequent years, these earlier reports, together with the unusual sequence of publication by the original discoverers, have led to considerable confusion concerning who the discoverers were, because various writers have apparently assumed that publication dates reflected discovery dates and therefore priorities. On occasion, a discoverer himself contributed to the muddle. A reference in 1953 to Kraus as "the discoverer of 2,4-D" (Anonymous 1953b, p.818) provoked a quick response from Jones, who asserted his own priority without mentioning that of any others (Jones 1953).

Complicating the situation further, a spate of articles too numerous to cite here appeared in the popular and agricultural presses in 1945. Some of these mentioned only work in the United States (for example Carleton 1945; Cates 1945; Snyder 1945; Tukey 1945), and others were based only on the British results (for example Anonymous 1945a, 1945g, 1945h; Templeman 1945). While such revelations publicized the new weedkillers widely, they did not cover the complete story of the quadruple discovery and thus contributed to the confusion.

Aftermath of the Discovery

Military Plant Destruction

After becoming publicly known, the discovery of the hormone herbicides was quickly translated into practical applications of great importance. These were not military, however, even though such possible use had motivated much wartime support for the research. The British had rejected the idea of crop destruction on technical, political, and moral grounds (Clark 1965; Kirby 1980). In the United States, the program of the Chemical Warfare Service did not reach fruition before World War II ended in 1945 (Brophy et al. 1959). Only later were the herbicides put to actual use for defoliation and crop destruction, first by the British in Malaya from 1951 to 1953 (Adams 1990; Murphy at al. 1984), and then by the United States in Vietnam beginning in 1962 (Bovey and Young 1980).

Agricultural Applications

Agricultural use of the herbicides was a different story. Publicity concerning them in the popular press created a huge demand for the chemicals. In 1945, Amchem in the United States began marketing a form of 2,4-D under the trade name Weedone, and ICI in the United Kingdom began selling MCPA as Methoxone. Annual commercial production of the herbicides grew from less than one million pounds in 1945 to more than 30 million in 1952 and to more than 60 million in later years (Canine 1995; Sanders and Prescott 1959). This boom in production could occur because just at this time, chemical companies possessed facilities that had expanded greatly during the war and were now seeking new products to make and sell. A number of them began to produce the herbicides; in effect, a new industry was born. The discovery also had other ramifications. For one, machinery manufacturers developed new devices for applying the chemicals as sprays or dusts in the relatively minute quantities that were appropriate. For another, scientific and technological researchers began to seek other substances active as selective herbicides against various kinds of plants—an effort that has led to the large number of such agents available today.

The Patent Situation

The fact that a number of chemical companies began marketing 2,4-D and its relatives in 1945 produced a ticklish patent situation. The Jones–Amchem patent covered the use of the substances as weedkillers, not their manufacture and sale as a chemical. However, some of the companies were advertising their new products for that use, apparently in the belief that the patent would not stand up in the courts. Such a view was widely held (Anonymous 1946b). When the patent was first announced, one writer (Anony-

mous 1946c, p. 121) thought that "the very sweeping claims made in the patent may provoke some tense legal battles." This view was correct. The Sherwin-Williams Company brought the matter to a head when it filed a lawsuit against Amchem in Federal court on March 16, 1946, asking that the patent be declared invalid (Anonymous 1946d; Sherwin-Williams Co. v. American Chemical Paint Co. 1947). The Dow Chemical Company filed a similar suit on May 28. Amchem quickly entered counterclaims, charging patent infringement (American Chemical Paint Co. v. Dow Chemical Co. 1947; Anonymous 1946e). After the customary legal maneuvering, the matter was eventually settled out of court in October 1947 (Anonymous 1947). The settlement provided that Amchem would license all other manufacturers upon payment of only modest royalties, thus clarifying the situation. The earlier British patent did not figure in these events, although pursuant to regulations governing wartime conditions it was recognized in the United States in 1948 (Sexton et al. 1948).

Recognition of the Discoverers

The finding of the first hormone herbicides changed agricultural weed control practices dramatically. In this complex case of quadruple independent discovery, each of the four discovering groups played an important role. Recognition of various sorts eventually came to some of the individuals involved. In 1958 Templeman and Sexton jointly received the research medal of the Royal Agricultural Society of England (Anonymous 1958a, 1958b). Templeman in 1979 was made an Officer of the Order of the British Empire in recognition of his work (Anonymous 1979a), and upon his death on November 24 of that year, his obituary noted that he "will always have an honoured place in agricultural research for his part in the discovery of hormone selective weed killers" (Anonymous 1979b, p. 12). In death, Jones and Kraus received similar praise. Jones, who had received an honorary Sc.D. degree from Bucknell University in 1946, was lauded as the discoverer of 2,4-D (Anonymous 1964a, 1964b, 1964c). Of Kraus it was said that "his work led to the development of 2,4-D" (Anonymous 1960, p. 33) and that he did important work in the use of chemicals for weed control (Ashby 1960; Bailey 1960) which "helped greatly to develop 2,4-dichlorophenoxyacetic acid" (Murneek 1960, p. 544). In fact, all of the persons involved in this complicated discovery deserve credit for their parts in initiating an agricultural revolution.

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